



Office de la Propriété  
Intellectuelle  
du Canada

Un organisme  
d'Industrie Canada

Canadian  
Intellectual Property  
Office

An agency of  
Industry Canada

CA 2198706 C 2008/07/08

(11)(21) **2 198 706**

(12) **BREVET CANADIEN  
CANADIAN PATENT**

(13) **C**

(86) Date de dépôt PCT/PCT Filing Date: 1995/09/21  
(87) Date publication PCT/PCT Publication Date: 1996/03/28  
(45) Date de délivrance/Issue Date: 2008/07/08  
(85) Entrée phase nationale/National Entry: 1997/02/27  
(86) N° demande PCT/PCT Application No.: US 1995/012404  
(87) N° publication PCT/PCT Publication No.: 1996/009043  
(30) Priorité/Priority: 1994/09/23 (US08/311,489)

(51) Cl.Int./Int.Cl. *A61K 39/395* (2006.01),  
*A61P 19/02* (2006.01), *A61P 29/00* (2006.01),  
*C07K 16/18* (2006.01)  
(72) Inventeurs/Inventors:  
WANG, YI, US;  
MATIS, LOUIS, US  
(73) Propriétaire/Owner:  
ALEXION PHARMACEUTICALS, INC., US  
(74) Agent: MCFADDEN, FINCHAM

(54) Titre : PROCÉDES DE TRAITEMENT DE L'ARTHRITE

(54) Title: METHODS FOR THE TREATMENT OF INFLAMMATORY JOINT DISEASE

(57) Abrégé/Abstract:

The use of compounds that block complement component C5 or its active fragments C5a and/or C5b (such compounds collectively referred to as "C5 blockers") to treat established joint inflammation (arthritis) is disclosed. Administration of such C5 blockers has been found to: 1) arrest and/or reduce inflammation in joints which are already inflamed, and 2) inhibit the spread of inflammation to unaffected joints.



PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>A61K 31/395, 31/34, C07D 307/94, C07K 16/18, 16/40</b>		<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 96/09043</b>
			<b>(43) International Publication Date:</b> 28 March 1996 (28.03.96)
<b>(21) International Application Number:</b> PCT/US95/12404		<b>(81) Designated States:</b> AU, CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).	
<b>(22) International Filing Date:</b> 21 September 1995 (21.09.95)		<div style="text-align: center;"><b>2198706</b></div> <p><b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
<b>(30) Priority Data:</b> 08/311,489                      23 September 1994 (23.09.94)    US			
<b>(71) Applicant:</b> ALEXION PHARMACEUTICALS, INC. [US/US]; Suite 360, 25 Science Park, New Haven, CT 06511 (US).			
<b>(72) Inventors:</b> WANG, Yi; 270 Sylvan Valley Road, Orange, CT 06477 (US). MATIS, Louis; 775 Flintlock Road, Southport, CT 06490 (US).			
<b>(74) Agent:</b> KLEE, Maurice, M.; 1951 Burr Street, Fairfield, CT 06430 (US).			
<b>(54) Title:</b> METHODS FOR THE TREATMENT OF INFLAMMATORY JOINT DISEASE			
<b>(57) Abstract</b>  The use of compounds that block complement component C5 or its active fragments C5a and/or C5b (such compounds collectively referred to as "C5 blockers") to treat established joint inflammation (arthritis) is disclosed. Administration of such C5 blockers has been found to: 1) arrest and/or reduce inflammation in joints which are already inflamed, and 2) inhibit the spread of inflammation to unaffected joints.			

- 50 -

**CLAIMS:**

1. Use of an effective anti-inflammatory amount of an anti-C5 monoclonal antibody for the treatment of established joint inflammation.
2. The use of claim 1, wherein the anti-C5 monoclonal antibody is in an amount sufficient to substantially inhibit a cell-lysing ability of complement present in a blood-derived fluid of a patient.
3. The use of claim 2, wherein the blood-derived fluid is serum.
4. The use of claim 1, wherein the anti-C5 monoclonal antibody is in an amount sufficient to substantially reduce a level of soluble C5b-9 present in a blood-derived fluid of a patient after activation of complement in that fluid.
5. The use of claim 4, wherein the blood-derived fluid is serum.
6. The use of claim 1, wherein the anti-C5 monoclonal antibody is in an amount sufficient to substantially reduce a level of C5a present in a blood-derived fluid of a patient after activation of complement in that fluid.
7. The use of claim 6, wherein the blood-derived fluid is serum.
8. The use of claim 1, wherein the anti-C5 monoclonal antibody is in an amount sufficient to reduce a cell-lysing ability of complement present in synovial fluid of an inflamed joint of a patient by at least 10%.
9. The use of claim 1, wherein the anti-C5 monoclonal antibody is in an amount sufficient to reduce a level of soluble C5b-9 present in synovial fluid of an inflamed joint of a patient by at least 10%.
10. The use of claim 1, wherein the anti-C5 monoclonal antibody is in an amount sufficient to reduce a level of C5a present in synovial fluid of an inflamed joint of a patient by at least 10%.
11. The use of claim 1, wherein the anti-C5 monoclonal antibody does not substantially interfere with cleavage of

- 51 -

complement component C3 in a patient's serum into C3a and C3b.

12. An article of manufacture comprising packaging material and a pharmaceutical agent contained within said packaging material, wherein:

(a) said pharmaceutical agent comprises an anti-C5 monoclonal antibody which provides the agent with anti-inflammatory properties; and

(b) said packaging material comprises a label which indicates that said pharmaceutical agent is for use in the treatment of joint inflammation.

13. An article of manufacture comprising packaging material and a pharmaceutical agent contained within said packaging material, wherein:

(a) said pharmaceutical agent comprises an anti-C5 monoclonal antibody which provides the agent with anti-inflammatory properties; and

(b) said packaging material comprises a label which indicates that said pharmaceutical agent is for use in the treatment of arthritis.

5     METHODS FOR THE TREATMENT OF INFLAMMATORY JOINT DISEASEFIELD OF THE INVENTION

10     The present invention relates to methods for the treatment of inflammatory joint disease. In particular, the invention relates to the use of blockers of complement component C5 ("C5 blockers") as pharmaceutical agents to treat established joint inflammation.

BACKGROUND OF THE INVENTIONI.   The Complement System

15     The complement system acts in conjunction with other immunological systems of the body to defend against intrusion of cellular and viral pathogens. There are at least 25 complement proteins, which are found as a complex collection of plasma proteins and membrane cofactors. The plasma proteins (which are also found in  
20     most other body fluids, such as lymph, bone marrow, synovial fluid, and cerebrospinal fluid) make up about 10% of the globulins in vertebrate serum. Complement components achieve their immune defensive functions by  
25     interacting in a series of intricate but precise enzymatic cleavage and membrane binding events. The resulting complement cascade leads to the production of products with opsonic, immunoregulatory, and lytic functions.

30     The complement cascade progresses via the classical pathway or the alternative pathway. These pathways share many components, and, while they differ in their early steps, both converge and share the same terminal complement components responsible for the destruction of  
35     target cells and viruses.

      The classical complement pathway is typically initiated by antibody recognition of and binding to an

2198706

antigenic site on a target cell. This surface bound antibody subsequently reacts with the first component of complement, C1. The C1 thus bound undergoes a set of autocatalytic reactions that result in, inter alia, the  
5 induction of C1 proteolytic activity acting on complement components C2 and C4.

This activated C1 cleaves C2 and C4 into C2a, C2b, C4a, and C4b. The function of C2b is poorly understood. C2a and C4b combine to form the C4b,2a complex, which is  
10 an active protease known as classical C3 convertase. C4b,2a acts to cleave C3 into C3a and C3b. C3a and C4a are both relatively weak anaphylatoxins that may induce degranulation of mast cells, resulting in the release of histamine and other mediators of inflammation.

C3b has multiple functions. As opsonin, it binds to  
15 bacteria, viruses and other cells and particles and tags them for removal from the circulation. C3b can also form a complex with C4b,C2a to produce C4b,2a,3b, or classical C5 convertase, which cleaves C5 into C5a (another anaphylatoxin), and C5b. Alternative C5 convertase is  
20 C3b, Bb, C3b and performs the same function. C5b combines with C6 yielding C5b,6, and this complex combines with C7 to form the ternary complex C5b,6,7. The C5b,6,7 complex binds C8 at the surface of a cell  
25 membrane. Upon binding of C9, the complete membrane attack complex (MAC) is formed (C5b-9) which mediates the lysis of foreign cells, microorganisms, and viruses.

Further discussions of the classical complement pathway, as well as a detailed description of the  
30 alternative pathway of complement activation, can be found in numerous publications including, for example, Roitt, et al., 1988, and Muller-Eberhard, 1988.

## II. Joint Inflammation

A variety of common medical disorders have as a  
35 common element the inflammation of the patient's joints. In the United States alone, millions of patients suffer from such joint inflammation. Afflicted individuals are

frequently disabled, and the costs of medical care for patients suffering from such disorders are significant. While numerous means are available for treatment of joint inflammation, and new treatments continue to become  
5 available, none of these is as safe and effective as could be desired, and there has thus been a long felt need for new approaches and better methods to control joint inflammation.

Clinically, joint inflammation is associated with  
10 joint stiffness, pain, weakness, and sometimes joint fatigue. Uniformly, the joint is tender and swollen, and often erythematous. Diagnosis of the inflammatory nature of the joint disease is frequently based upon this typical clinical presentation as well as upon  
15 radiographic examination and aspiration and examination of synovial joint fluid. Examination of joint fluid of an inflamed joint generally reveals elevation of various markers of inflammation, such as, leukocytes (including neutrophils), antibodies, cytokines, cell adhesion  
20 molecules, and complement activation products (De Clerck et al., 1989; Heinz et al., 1989; Moffat et al., 1989; Peake et al., 1989; Brodeur et al., 1991; Firestein et al., 1991; Matsubara et al., 1991; Olsen et al., 1991; Oleesky et al., 1991; Jose et al., 1990; Zvaifler, 1968;  
25 Zvaifler, 1969a; Zvaifler, 1969b; Zvaifler, 1974; Ward and Zvaifler, 1971; Ward, 1975; Moxley and Ruddy, 1985; Mollnes et al., 1986; Auda et al., 1990; Olmez et al., 1991; Kahle et al., 1992; Koch et al., 1994; Thorbecke et al., 1992; Saura et al., 1992; Feldman et al., 1990;  
30 Feldman et al., 1991; Fong et al., 1994; Harigi et al., 1993; Morgan et al., 1988; Shingu et al., 1994; Abbink et al., 1992; and Corvetta et al., 1992). Radiographic examination of affected joints generally reveals soft tissue swelling and/or erosive changes.

35 Joint inflammation is associated with a group of diseases that are referred to medically as arthritides (types of arthritis). The term "arthritis" is used

- 4 -

medically to generally describe diseases of the joints. The term, however, is also used to describe certain medical conditions, of which rheumatoid arthritis (RA) is the primary  
5 example, that consist of a multiplicity of different pathologic manifestations, including, but by no means limited to, joint disease.

Discussions of arthritis may thus include diseases such as RA, where joint disorders are only one facet of the varied  
10 pathologies associated with the disease. The present invention is directed specifically to the joint disorder aspects of these diseases. The methods of the invention, however, may also have beneficial effects on non-joint-associated pathologies. For example, use of the methods of the invention to treat  
15 established joint inflammation associated with RA, psoriasis, lupus, and other disorders may also provide therapeutic benefits impacting on some of the other pathologic manifestations of these multifaceted disease states, such as vascular inflammation and nephritis (see, for example, Wurzner, et al., Complement  
20 Inflamm., 8:328-340, 1991, U.S. Patent No. 5,853,722 and U.S. Patent No. 6,074,642, and Sims, et al., U.S. Patent No. 5,135,916).

It should be noted that the present invention is not concerned with all types of joint disorders, but only those  
25 involving inflammation. Thus, for example, the invention is applicable to the treatment of late stage osteoarthritis (OA), which is an inflammatory joint disease, but generally not to early stage OA, which does not typically have a significant inflammatory component.

30 Detailed discussions of the arthritides can be found in numerous medical texts, including Arnett, 1992, Cecil Textbook of Medicine, Wyngaarden et al. (eds.), W.B. Saunders Company, Philadelphia, Chapter 258, pp. 1508-1515; Lipsky, 1994, Harrison's Principles of Internal Medicine, 13<sup>th</sup> Ed.,  
35 Isselbacher et al. (eds), McGraw-Hill, Inc., New York, Chapter 285, pp. 1648-1655;



and McCarty and Koopman, 1993. Arthritis and Allied Conditions, 12th Ed. Lea and Febiger, Philadelphia. As discussed in detail in these and other texts, and reviewed below, joint inflammation is associated with numerous local and systemic disease processes.

Factors Associated with Joint Inflammation

Joint inflammation is a complex process involving, among other things, activation of both cellular and humoral immune responses.

Cellular immune responses include infiltration by white blood cells, predominantly neutrophils (also referred to as polymorphonuclear cells or PMNs). Mononuclear white blood cell infiltrates are also common in many inflamed joints. Infiltrating mononuclear cells, including T lymphocytes (as well as cells resident within the joint such as synovial cells, fibroblasts, and endothelial cells) are activated and contribute to the production of multiple inflammatory cytokines including TNF- $\alpha$ , IL-1, IFN- $\gamma$ , IL-2, IL-6, IL-8, GM-CSF, PDGF and FGF, these latter two being capable of stimulating synovial cell proliferation.

All of these cytokines are thought to play a role in inducing the production of numerous other inflammatory factors as well as various other mediators of tissue degradation. These factors and mediators of degradation include products of arachidonic acid metabolism (that are active in various intracellular signal transduction pathways), reactive oxygen intermediates, and degradative enzymes such as collagenase, stromelysin, and other neutral proteases, all of which can further contribute to the inflammatory response and to tissue destruction.

Cellular infiltration into the synovium is enhanced by the upregulation of cell adhesion molecules such as selectins, LFA-3, and members of the ICAM family of Ig-like cell adhesion molecules on cells within the joint. These adhesion molecules promote the infiltration of activated white blood cells into the affected joint by

2198706

stimulating leukocyte (including lymphocyte) adhesion, migration, and activation.

5 The humoral immune system also contributes to joint inflammation. Antibodies are produced within inflamed joints in such diseases as RA, JRA and OA (see below) and generate localized immune complexes that can activate the complement system. As discussed above in greater detail, activated complement components can have cytolytic, cell activating, anaphylatoxic, and chemotactic effects.

10 These multifactorial inflammatory responses lead to cartilage destruction and bone erosion that ultimately result in the joint deformity seen in patients with chronic joint inflammation.

15 In view of the complex nature of joint inflammation, a variety of theories, many of which are conflicting, have been proposed in the art to explain the relative importance of the various factors involved. Notwithstanding extensive work, there remains a basic controversy in the art as to the relative roles of the cellular and humoral immune systems in joint inflammation, including what role complement plays in such inflammation. See, for example, Andersson and Holmdahl, 1990; Brahn and Trentham, 1989; Chiocchia et al., 1990; Chiocchia et al., 1991; Durie et al., 1993; 20 Goldschmidt et al., 1990; Goldschmidt and Holmdahl, 1991; Holmdahl et al., 1985; Holmdahl et al., 1989; Holmdahl et al., 1990; Hom et al., 1988; Hom et al., 1992; Hom et al., 1993; Mori et al., 1992; Myers et al., 1989A; Nakajima et al., 1993; Osman et al., 1993; Peterman et al., 1993; Seki et al., 1988; Seki et al., 1992; Terato et al., 1992; Watson et al., 1987; and, in particular, the following reports relating to the complement system and/or the relative roles of T cells and complement components in joint inflammation: Andersson et al., 35 1991; Andersson et al., 1992; Banerjee et al., 1988B; Banerjee et al., 1989; David, 1992; Fava et al., 1993; Haqqi et al., 1989; Kakimoto et al., 1988; Maeurer et

al., 1992; Morgan et al., 1981; Moxley and Ruddy, 1985; Reife et al., 1991; Spinella et al., 1991; Spinella and Stuart, 1992; van Lent et al., 1992; Watson et al., 1987; Watson and Townes, 1985; and Williams et al., 1992A. To  
5 date, these wide ranging studies have not led to effective treatments for established joint inflammation based on modulation of the complement system and, in particular, based on the use of C5 blockers.

The studies of the prophylactic effects of C5  
10 blockers reported below in Example 2 were designed to determine if C5 was an appropriate and effective target for pharmacological modulation of the humoral immune system in order to prevent joint inflammation. The surprising effectiveness of C5 blockers in preventing  
15 onset of joint inflammation led to the design and execution of the studies reported in Example 1 in which C5 blockers were used to treat established inflammation. At the outset of these experiments, it was anticipated that such treatment would have little measurable effect  
20 upon established joint inflammation, as it was supposed that C5 was more important early in the disease process when the chemotactic activity of C5a would trigger the infiltration of inflammatory cells. It was further supposed that the involvement of T cells in established  
25 disease would continue to provide significant inflammatory stimuli even in the absence of C5 activity. As shown by the results of Example 1 this expectation was incorrect in that C5 blockers were found to be surprisingly effective in arresting and/or reducing the  
30 inflammation of joints which were already inflamed, while at the same time inhibiting the spread of inflammation to unaffected joints.

#### Diseases Commonly Associated with Joint Inflammation

Rheumatoid arthritis (RA) and juvenile onset  
35 rheumatoid arthritis (JRA) are chronic multisystem diseases of unknown cause. RA affects approximately 1% of the population, with women affected three times more

2198706

commonly than men. The onset is most frequent during the fourth and fifth decades of life. RA and JRA are systemic diseases with numerous pathologic manifestations in addition to their joint inflammatory aspects. In RA, these manifestations include RA vasculitis (inflammation of the blood vessels), which can affect nearly any organ system and can cause numerous pathologic sequelae including polyneuropathy, cutaneous ulceration, and visceral infarction. Pleuropulmonary manifestations include pleuritis, interstitial fibrosis, pleuropulmonary nodules, pneumonitis, and arteritis. Other manifestations include the development of inflammatory rheumatoid nodules on a variety of periarticular structures such as extensor surfaces, as well as on pleura and meninges. Weakness and atrophy of skeletal muscle are common.

The joint inflammation aspects of RA present as persistent inflammatory synovitis, usually involving peripheral joints in a symmetric distribution. In general, the complex intraarticular inflammatory response seen in RA is of the type described above in the general discussion of joint inflammation.

Many patients with systemic lupus erythematosus (SLE) also develop joint inflammation referred to as lupus arthritis. SLE is an autoimmune disease of unknown cause in which numerous different cells, tissues, and organs are damaged by pathogenic autoantibodies and immune complexes. Clinical manifestations of SLE are numerous and include a variety of maculopapular rashes, nephritis, cerebritis, vasculitis, hematologic abnormalities including cytopenias and coagulopathies, pericarditis, myocarditis, pleurisy, gastrointestinal symptoms, and the aforementioned joint inflammation.

Osteoarthritis (OA) represents the most common joint disease of mankind, and OA of the knee is the leading cause of chronic disability in developed countries. It is manifested by pain, stiffness, and swelling of the

involved joints. Articular cartilage, responsible for the most critical mechanical functions of the joint, is the major target tissue of OA. The breakdown of articular cartilage in OA is mediated by various enzymes such as metalloproteinases, plasmin, and cathepsin, which are in turn stimulated by various factors that can also act as inflammatory mediators. These factors include cytokines such as interleukin-1, which is known to activate the pathogenic cartilage and synovial proteases.

The identification of above normal levels of immunoglobulins in cartilage in generalized OA and the demonstration of type II collagen-specific antibodies in some OA patients provide evidence of a role for immune activation in this disease state (see, for example, Jasin, 1989). The observation that OA rarely remains monoarticular also suggests that this disease is a systemic disorder of articular cartilage. Synovial inflammation becomes more frequent as the disease progresses. In fact, in late stage OA, histologic evidence of synovial inflammation may be as marked as that in the synovium of patients with RA-associated joint inflammation.

Psoriatic arthritis is a chronic inflammatory joint disorder that affects 5 to 8% of people with psoriasis. A significant percentage of these individuals (one-fourth) develop progressive destructive disease. Twenty-five percent of psoriasis patients with joint inflammation develop symmetric joint inflammation resembling the joint inflammation manifestations of RA, and over half of these go on to develop varying degrees of joint destruction.

#### Other Diseases Associated with Joint Inflammation

A variety of other systemic illnesses have joint inflammation as a prominent feature of the clinical presentation.

Peripheral joint inflammation occurs in as many as one-fifth of patients with inflammatory bowel disease.

2198706

The joint inflammation is acute, associated with flare-ups of the bowel disease, and is manifested by swollen, erythematous, warm, and painful joints. Synovial fluids of sufferers have an acute inflammatory exudate of mostly neutrophils, and radiographs demonstrate soft tissue swelling and effusions.

The synovitis that accompanies hepatitis B resembles serum sickness, with abrupt onset of fever and articular inflammation. There is generally a symmetric inflammation of joints including the knee, shoulder, wrist, ankles, elbow, and the joints of the hands. Immune complexes containing hepatitis B antigens are present in serum and synovium, lending support to the concept that the synovitis is immunologically mediated. Other viral diseases associated with joint inflammation include rubella, human immunodeficiency virus infection, coxsackieviral, and adenoviral infections.

An immune complex mediated joint inflammation is also associated with intestinal bypass surgery, and joint inflammation is a prominent manifestation of Whipple's disease, or intestinal lipodystrophy, where fever, edema, serositis, lymphadenopathy, uveitis, and cerebral inflammation are associated findings. Furthermore, potentially immunologically-related joint inflammation is an associated sequelum of infectious endocarditis and certain spirochetal infections, most notably infection with Borrelia burgdorferi, the causative organism of Lyme disease.

Primary Sjögrens syndrome is a chronic, slowly progressive autoimmune disease characterized by lymphocytic infiltration of the exocrine glands resulting in xerostomia and dry eyes. One-third of patients present with systemic manifestations, including vasculitis, nephritis, mononeuritis multiplex, and, most commonly, joint inflammation.

Ankylosing spondylitis (AS) is an inflammatory disorder of unknown cause that affects primarily the

axial skeleton, but peripheral joints are also affected. Its incidence correlates with the HLA-B27 histocompatibility haplotype, and immune-mediated mechanisms are further implicated by elevated serum levels of IgA and an inflammatory joint histology with similar characteristics to those seen in the joint inflammation aspects of RA. Thus, synovial fluid from inflammatory peripheral joints in AS is not distinctly different from that of other inflammatory joint diseases.

Reactive arthritis (ReA) refers to acute nonpurulent joint inflammation complicating an infection elsewhere in the body. Reactive arthritis is believed to be immunologically mediated. Included in this category is the constellation of clinical findings often referred to as Reiter's syndrome or Reiter's disease. In addition to joint inflammation, this syndrome affects the skin, eyes, mucous membranes, and less commonly the heart, lungs, and nervous system. Reiter's syndrome may follow enteric infections with any of several Shigella, Salmonella, Yersinia, and Campylobacter species, and genital infections with Chlamydia trachomatis. The histology of joints affected by this syndrome is similar to that seen in other types of joint inflammation. The joint inflammation is usually quite painful, and tense joint effusions are not uncommon, especially in the knee. The joint inflammation is usually asymmetric and additive, with involvement of new joints occurring over a period of a few days to several weeks.

### III. Current Therapies

Current therapies for the various types of joint inflammation discussed above include the administration of anti-inflammatory drugs such as non-steroidal drugs, including aspirin, and non-specific immunosuppressive drugs, such as gold compounds, corticosteroids, penicillamine, hydroxychloroquine, methotrexate, azathioprine, alkylating agents such as cyclophosphamide, and sulfasalazine. Administration of each of these

2198706

agents is sometimes associated with severe side effects and toxicities. Patients receiving certain of these treatments are also exposed to the dangers of opportunistic infection and increased risk of neoplasia associated with generalized immunosuppression. In addition to the medical texts cited above, discussions of drugs used to treat established joint inflammation can be found in Goodman and Gilman's The Pharmacological Basis of Therapeutics 18th Ed., Gilman et al. (eds.) 1990, Pergamon Press, Inc., New York, Chapter 26, pp. 638-681; Physician's Desk Reference 47th Ed., 1993, Medical Economics Co., Inc., Montvale, NJ; The United States Pharmacopeia 22nd Ed., 1989, Mack Printing Co., Easton, PA; Drug Evaluations Annual 1991, 1990, American Medical Association, Milwaukee, WI; and Cash and Klippel, 1994, N. Eng. J. Med. 330, pp. 1368-1375.

In addition to pharmacologic treatments, relief of the symptoms of joint inflammation is sometimes achieved with warm or cold soaks. Surgical intervention using tendon release procedures and/or joint replacement procedures is frequently the last resort for treatment of chronic joint inflammation. Such orthopedic surgery is associated with increased infection and prostheses have limited life spans.

New therapeutic approaches currently being developed include attempts to address various elements of the cellular immune response contributing to the inflammatory cascade present in inflamed joints. These approaches include the administration of therapeutic preparations including anti-T cell and/or anti-cytokine agents (see, for example, Banerjee et al., 1988A; Cannon et al., 1990; Chiocchia et al., 1991; Elliot et al., 1993; Fava et al., 1993; Fujimori et al., 1993; Griswold et al., 1988; Hom et al., 1988; Hom et al., 1991; Hom et al., 1993; Inoue et al., 1993; Kakimoto et al., 1992; Kleinau et al., 1989; Myers et al., 1989b; Myers et al., 1993; Nagler-Anderson et al., 1986; Nishikaku and Koga, 1993; Peterman



- 13 -

et al., 1993; Piguet et al., 1992; Smith et al., 1990; Spannaus-  
Martin et al., 1990; Thompson et al., 1988; Trentham et al.,  
1993; Williams et al., 1992b; Williams et al., 1994; and Wolos et  
5 al., 1993).

#### SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present  
invention to provide a new approach for treating established  
joint inflammation.

10 To achieve this goal, the invention provides methods  
involving the use of blockers of complement component C5 as  
pharmaceutical agents to accomplish therapeutic treatment of  
established joint inflammation. The C5 blockers are  
administered to animals, e.g., humans, having at least one  
15 inflamed joint. The blockers can be administered systemically or  
locally. They achieve a reduction or stabilization of the  
inflammation of joints that are already inflamed and inhibit the  
spread of inflammation to unaffected joints.

In accordance with an embodiment of the present  
20 invention there is provided use of an effective anti-  
inflammatory amount of an anti-C5 monoclonal antibody for the  
treatment of established joint inflammation.

Yet another embodiment of the present invention  
provides an article of manufacture comprising packaging  
25 material and a pharmaceutical agent contained within the  
packaging material, wherein: (a) the pharmaceutical agent  
comprises an anti-C5 monoclonal antibody which provides the  
agent with anti-inflammatory properties; and (b) the packaging  
material comprises a label which indicates that the  
30 pharmaceutical agent is for use in the treatment of joint  
inflammation.

A still further embodiment of the present invention  
provides an article of manufacture comprising packaging material  
and a pharmaceutical agent contained within the packaging  
35 material, wherein: (a) the pharmaceutical agent comprises an  
anti-C5 monoclonal antibody which provides the agent with anti-  
inflammatory properties; and (b) the packaging material

- 13a -

comprises a label which indicates that the pharmaceutical agent  
5 is for use in the treatment of arthritis.

As used herein, a "C5 blocker" is a compound that directly  
interacts with C5, C5a, and/or C5b, i.e., a compound that  
directly binds to or directly modified (i.e., by a direct  
chemical reaction) one of these complement components, so as to  
10 inhibit the formation of and/or physiologic function of C5a  
and/or C5b. Preferably, the formation and/or physiologic  
functions of both C5a and C5b are inhibited by the C5 blocker.

Direct interaction with C5, C5a, and/or C5b has the  
important advantage that other components of the complement  
15 cascade may be left intact. In particular, the opsonization  
functions associated with the activation of complement component  
C3 by a C3 convertase to yield C3a and C3b may be left intact  
allowing for continued clearance of foreign particles and  
substances from the body by the action of C3b. The most  
20 preferred C5 blockers are those which are of this type, i.e.,  
those that do not interfere with C3b function.

25

30

35

2198706

As demonstrated by the examples presented below, in accordance with the invention, it has been surprisingly found that treatment with C5 blockers will arrest and, in many cases, at least partially reverse the disease process at an inflamed joint, while at the same time preventing progression of joint inflammation to non-affected joints. Given the prior understanding in the art regarding the role of the cellular immune system in joint inflammation (see above), one would not have expected that a C5 blocker would have such a dramatic beneficial effect on established joint inflammation.

The accompanying figures, which are incorporated in and constitute part of the specification, illustrate certain aspects of the invention, and together with the description, serve to explain the principles of the invention. It is to be understood, of course, that both the figures and the description are explanatory only and are not restrictive of the invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a-c are photomicrographs of joints stained with Hematoxylin and Eosin illustrating the use of a C5 blocker to stop the progression of established joint inflammation. Figure 1a shows a paw joint from a normal mouse; Figure 1b shows an initially affected paw joint from a control treated mouse, where the joint exhibits extensive bone erosion with severe inflammatory cell infiltration and thickening of the synovial membrane; and Figure 1c shows an initially affected paw joint from a C5 blocker treated mouse showing preserved joint structure with some degree of synovial membrane thickening and a surprising lack of polymorphonuclear cell infiltration compared with the initially affected joint from the control group (Figure 1b).

Figures 2a-b are plots demonstrating the ability of a C5 blocker to stop the progression of pathology of an inflamed joint. Figure 2a shows a comparison of mean joint inflammation (JI) index values. Data represent

mean JI index  $\pm$  standard error. Solid circles are C5 blocker treated mice (n=6). Open circles are control treated mice (n=4). Figure 2b shows a comparison of paw thickness of initially affected joints. After onset of joint inflammation, control paw thickness increased significantly compared to treated or normal (N) paws. Data represent mean thickness  $\pm$  SE. Solid circles are C5 blocker treated mice (n=8). Open circles are control treated mice (n=4).

Figures 3a-e are plots of paw thickness versus time for C5 blocker treated and control treated mice. Figures 3a-d show measurements from initially affected paws of paired animals; Figure 3e shows measurements from initially affected paws of two unpaired treated animals and the mean control measurements of Figure 2b.

Figures 4a-c are photomicrographs of joints stained with Hematoxylin and Eosin illustrating the use of a C5 blocker to prevent the onset of joint inflammation. Figure 4a shows a paw joint from a normal mouse; Figure 4b shows an affected paw joint from a control treated mouse, where inflammatory cell infiltration, thickening of the synovial membrane and bone erosion by the expanding synovial pannus are visible; and Figure 4c shows a typical paw joint from a C5 blocker treated mouse showing only subclinical thickening of the synovial membrane.

Figure 5 shows that treatment with a C5 blocker prevents joint inflammation. Figure 5a is a comparison of the incidence of Collagen-Induced joint inflammation in C5 blocker treated mice (n=9) and in a pool of mice treated with two different control treatments (n=10). The data represent the overall (total) incidence of joint inflammation seen within two months after the initiation of treatment. Figure 5b is a comparison of serum hemolytic activity of C5 blocker treated mice (n=5) and control treated mice (n=3) two weeks after the initiation of treatment.

Figure 6 shows the effects of C5 blocker treatment on collagen-specific humoral and cellular responses. Figure 6a was prepared by analyzing serum samples obtained from C5 blocker treated (n=4) or control treated mice (n=4) at the indicated time after CII immunization. The samples were analyzed for anti B-CII IgG in an ELISA assay. The anti B-CII antibody index represents the ratio of optical densities obtained from positive serum and negative sera. Figure 6b was prepared by culturing lymph node T cells ( $5 \times 10^5$ ) in vitro with  $20 \mu\text{g/ml}$  B-CII, C-CII, B-CI or medium only, in the presence of  $5 \times 10^5$  of mitomycin C treated syngeneic spleen cells for a total of 4 days, following which the cells were pulsed with  $^3\text{H}$ -thymidine, 18 hours before harvest.

Figure 7 shows the results of hemolytic assays demonstrating inhibition of complement activity associated with human blood circulated through an extracorporeal circuit following treatment with a C5 blocker. Assays were performed before the addition of the blocker or the commencement of the CPB circuit ("Pre Tx") using undiluted blood ("undil") and diluted blood ("dil") as described in Example 4. Samples of diluted blood to which the blocker had been added ("Post Tx") were assayed at the times indicated after starting the CPB circuit.

Figure 8 shows the results of assays of levels of complement component C3a demonstrating that the generation of complement component C3a in whole human blood circulated through an extracorporeal circuit is not inhibited by the addition of a C5 blocker to such whole blood. Assays were performed before the addition of the blocker or the commencement of the CPB circuit ("Pre Tx") using undiluted blood ("undil") and diluted blood ("dil") as described in Example 5. Samples of diluted blood to which the blocker had been added ("Post Tx") were assayed at the times indicated after starting the CPB circuit.

Figure 9 shows the results of assays of the levels of soluble C5b-9 (sC5b-9) in human blood circulated through an extracorporeal circuit demonstrating that the addition of a C5 blocker to such whole blood inhibits the formation of the C5b-9 terminal complement assembly. Assays were performed before the addition of the blocker or the commencement of the CPB circuit ("Pre Tx") using undiluted blood ("undil") and diluted blood ("dil") as described in Example 6. Samples of diluted blood to which the blocker had been added ("Post Tx") were assayed at the times indicated after starting the CPB circuit.

Figures 10a-b show pharmacokinetic analyses of the reduction of the cell lysis ability of mouse blood (Fig. 10a) or extracorporeally circulating human blood (Fig. 10b) after treatment with various C5 blockers. C5 Blocker B is monoclonal antibody BB5.1; C5 Blocker F is an Fab' fragment of monoclonal antibody BB5.1; C5 Blocker N is monoclonal antibody N19-8.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

As discussed above, the present invention relates to a method for treating established joint inflammation by the administration of a C5 blocker or a combination of C5 blockers to a patient in need of such treatment. As used herein, "established joint inflammation" means that the patient has at least one inflamed joint at the time treatment is commenced.

Such C5 blockers comprise proteins (including antibodies), peptides, and other molecules that directly interact with C5, C5a, and/or C5b, so as to inhibit the formation of and/or physiologic function of C5a and/or C5b. Examples of non-protein molecules of this type include K-76 COOH, (see Hong et al., 1979), and substituted dihydrobenzofurans, spirobenzofuran-2(3H)-cycloalkanes, and their open chain intermediates, (see Sindelar et al., U.S. patent No. 5,173,499), that are reported to directly interact with C5, C5a, and/or C5b. Preferably, the C5 blocker or blockers inhibit the

formation of and/or physiologic function of both C5a and C5b.

5 The concentration and/or physiologic activity of C5a and C5b in a body fluid can be measured by methods well known in the art. For C5a such methods include chemotaxis assays, RIAs, or ELISAs (see, for example, Ward and Zvaifler, 1971; Jose et al., 1990; Wurzner et al., 1991). For C5b, hemolytic assays or assays for soluble C5b-9 as discussed herein can be used. Other  
10 assays known in the art can also be used. Using assays of these or other suitable types, candidate C5 blockers, now known or subsequently identified, can be screened in order to 1) identify compounds that are useful in the practice of the invention and 2) determine the  
15 appropriate dosage levels of such compounds. Examples 2, 4, and 6-8 illustrate the use of hemolytic and soluble C5b-9 assays with C5 blockers comprising monoclonal antibodies.

Blockers affecting C5a are preferably used at  
20 concentrations providing substantial reduction (i.e., reduction by at least about 25%) in the C5a levels present in at least one blood-derived fluid of the patient, e.g., blood, plasma, or serum, following activation of complement within the fluid.  
25 Alternatively, they are used at concentrations providing at least about a 10% reduction in the C5a levels present in the synovial fluid of an inflamed joint.

Similarly, blockers affecting C5b are preferably used at concentrations providing substantial reduction  
30 (i.e., reduction by at least about 25%) in the C5b levels present in at least one blood-derived fluid of the patient following activation of complement within the fluid. Alternatively, they are used at concentrations providing at least about a 10% reduction in the C5b  
35 levels present in the synovial fluid of an inflamed joint. In the case of C5b, such concentrations can be conveniently determined by measuring the cell-lysing

ability (e.g., hemolytic activity) of complement present in the fluid or the levels of soluble C5b-9 present in the fluid (see, for example, Example 6 below). Accordingly, a preferred concentration for a C5 blocker that affects C5b is one that results in a substantial reduction (i.e., a reduction by at least about 25%) in the cell-lysing ability of the complement present in at least one of the patient's blood-derived fluids. Reductions of the cell-lysing ability of complement present in the patient's body fluids can be measured by methods well known in the art such as, for example, by a conventional hemolytic assay such as the hemolysis assay described by Kabat and Mayer, 1961, pages 135-139, or a conventional variation of that assay such as the chicken erythrocyte hemolysis method described below.

Preferred C5 blockers are relatively specific, and do not block the functions of early complement components. In particular, such preferred agents will not substantially impair the opsonization functions associated with complement component C3b, which functions provide a means for clearance of foreign particles and substances from the body.

C3b is generated by the cleavage of C3, which is carried out by classical and/or alternative C3 convertases, and results in the generation of both C3a and C3b. Therefore, in order not to impair the opsonization functions associated with C3b, preferred C5 blockers do not substantially interfere with the cleavage of complement component C3 in a body fluid of the patient (e.g., serum) into C3a and C3b. Such interference with the cleavage of C3 can be detected by measuring body fluid levels of C3a and/or C3b, which are produced in equimolar ratios by the actions of the C3 convertases. Such measurements are informative because C3a and C3b levels will be reduced (compared to a matched sample without the C5 blocker) if cleavage is interfered with by a C5 blocker.



In practice, the quantitative measurement of such cleavage is generally more accurate when carried out by the measurement of body fluid C3a levels rather than of body fluid C3b levels, since C3a remains in the fluid phase whereas C3b is rapidly cleared. C3a levels in a body fluid can be measured by methods well known in the art such as, for example, by using a commercially available C3a EIA kit, e.g., that sold by Quidel Corporation, San Diego, CA, according to the manufacturers specifications. Particularly preferred C5 blockers produce essentially no reduction in body fluid C3a levels following complement activation when tested in such assays.

Preferred C5 blocking agents include antibodies. The antibodies are preferably monoclonal, although polyclonal antibodies, which can be produced and screened by conventional techniques, can also be used if desired. Hybridomas producing monoclonal antibodies (mAbs) reactive with complement component C5 can be obtained using complement component C5, C5a, and/or C5b, preferably in purified form, as the immunogen.

The most preferred antibodies will prevent the cleavage of C5 to form C5a and C5b, thus preventing the generation of the anaphylatoxic activity associated with C5a and preventing the assembly of the membrane attack complex associated with C5b. As discussed above, in a particularly preferred embodiment, these C5 blocking antibodies will not impair the opsonization function associated with the action of C3b.

General methods for the immunization of animals (in this case with C5, C5a, and/or C5b), isolation of antibody producing cells, fusion of such cells with immortal cells (e.g., myeloma cells) to generate hybridomas secreting monoclonal antibodies, screening of hybridoma supernatants for reactivity of secreted monoclonal antibodies with a desired antigen (in this case the immunogen or a molecule containing the

immunogen), the preparation of quantities of such antibodies in hybridoma supernatants or ascites fluids, and for the purification and storage of such monoclonal antibodies, can be found in numerous publications. These include: Coligan, et al., eds. Current Protocols In Immunology, John Wiley & Sons, New York, 1992; Harlow and Lane, Antibodies, A Laboratory Manual, Cold Spring Harbor Laboratory, New York, 1988; Liddell and Cryer, A Practical Guide To Monoclonal Antibodies, John Wiley & Sons, Chichester, West Sussex, England, 1991; Montz, et al., Cellular Immunol. 127:337-351, 1990; Wurzner, et al., Complement Inflamm. 8:328-340, 1991; and Mollnes, et al., Scand. J. Immunol. 28:307-312, 1988.

A description of the preparation of a mouse anti-human-C5 monoclonal antibody with preferred binding characteristics is presented below in Example 8. Wurzner, et al., 1991, describe the preparation of other suitable mouse anti-human-C5 monoclonal antibodies referred to as N19-8 and N20-9.

As used herein, the terms "antibody" or "antibodies" refer to immunoglobulins produced in vivo, as well as those produced in vitro by a hybridoma, and antigen binding fragments (e.g., Fab' preparations) of such immunoglobulins, as well as to recombinantly expressed (engineered) antigen binding proteins, including immunoglobulins, chimeric immunoglobulins, "humanized" immunoglobulins, antigen binding fragments of such immunoglobulins, single chain antibodies, and other recombinant proteins containing antigen binding domains derived from immunoglobulins. As used herein, the term "monoclonal" refers to any antibody that is not of polyclonal origin.

Publications describing methods for the preparation of engineered antibodies, in addition to those listed immediately above, include: Reichmann, et al., Nature, 332:323-327, 1988; Winter and Milstein, Nature, 349:293-299, 1991; Clackson, et al., Nature, 352:624-628, 1991;

Morrison, Annu Rev Immunol, 10:239-265, 1992; Haber, Immunol Rev, 130:189-212, 1992; and Rodrigues, et al., J Immunol, 151:6954-6961, 1993. Human or humanized antibodies are preferred for administration to human patients.

To achieve the desired reductions of body fluid parameters, such anti-C5 antibodies can be administered in a variety of unit dosage forms. The dose will vary according to the particular antibody. For example, different antibodies may have different masses and/or affinities, and thus require different dosage levels. Antibodies prepared as Fab' fragments or single chain antibodies will also require differing dosages than the equivalent native immunoglobulins, as they are of considerably smaller mass than native immunoglobulins, and thus require lower dosages to reach the same molar levels in the patient's blood.

Dosage levels of the antibodies for human subjects are generally between about 0.5 mg per kg and about 100 mg per kg per patient per treatment, and preferably between about 1 mg per kg and about 50 mg per kg per patient per treatment. In terms of body fluid concentrations, the antibody concentrations are preferably in the range from about 5 µg/ml to about 500 µg/ml.

Other C5 blockers can also be administered in a variety of unit dosage forms and their dosages will also vary with the size, potency, and in vivo half-life of the particular C5 blocker being administered.

Doses of C5 blockers will also vary depending on the manner of administration, the particular symptoms of the patient being treated, the overall health, condition, size, and age of the patient, and the judgment of the prescribing physician.

Subject to the judgement of the physician, a typical therapeutic treatment includes a series of doses, which will usually be administered concurrently with the

monitoring of clinical endpoints such as number of joints involved, redness of joints, swelling of joints, mobility of joints, pain levels, etc., with the dosage levels adjusted as needed to achieve the desired clinical outcome.

The frequency of administration may also be adjusted according to various parameters. These include the clinical response, the plasma half-life of the C5 blocker, and the levels of the blocker in a body fluid, such as, blood, plasma, serum, or synovial fluid. To guide adjustment of the frequency of administration, levels of the C5 blocker in the body fluid may be monitored during the course of treatment.

Alternatively, for C5 blockers that affect C5b, levels of the cell-lysing ability of complement present in one or more of the patient's body fluids are monitored to determine if additional doses or higher or lower dosage levels are needed. Such doses are administered as required to maintain at least about a 25% reduction, and preferably about an 50% or greater reduction of the cell-lysing ability of complement present in blood, plasma, or serum, or at least about a 10% reduction of the cell-lysing ability of complement present in synovial fluid from an inflamed joint. The cell-lysing ability can be measured as percent hemolysis in hemolytic assays of the types described herein. A 10% or 25% or 50% reduction in the cell-lysing ability of complement present in a body fluid after treatment with the C5 blocker or blockers used in the practice of the invention means that the percent hemolysis after treatment is 90, 75, or 50 percent, respectively, of the percent hemolysis before treatment. In yet another alternative, dosage parameters are adjusted as needed to achieve a substantial reduction of C5a levels in blood, plasma, or serum, or at least a 10% reduction of the C5a levels in the synovial fluid of an inflamed joint. As discussed above, C5a levels can be measured using the techniques

described in Wurzner, et al., Complement Inflamm 8:328-340, 1991. Other protocols of administration can, of course, be used if desired as determined by the physician.

5 In a preferred embodiment, administration of the C5 blocker is initiated when the patient experiences a "flare up" of joint inflammation in which one or more affected joints becomes more swollen and takes on an erythematous (reddened) appearance.

10 Administration of the C5 blockers will generally be performed by a parenteral route, typically via injection such as intra-articular or intravascular injection (e.g., intravenous infusion) or intramuscular injection. Other routes of administration, e.g., oral (p.o.), may be used  
15 if desired and practicable for the particular C5 blocker to be administered.

For the treatment of established joint inflammation by systemic administration of a C5 blocker (as opposed to local administration, e.g., intra-articular injection  
20 into the inflamed joint) administration of a large initial dose is preferred, i.e., a single initial dose sufficient to yield a substantial reduction, and more preferably an at least about 50% reduction, in the hemolytic activity of the patient's serum. Such a large  
25 initial dose is preferably followed by regularly repeated administration of tapered doses as needed to maintain substantial reductions of serum hemolytic titer. In another embodiment, the initial dose is given by both local and systemic routes, followed by repeated systemic  
30 administration of tapered doses as described above.

Formulations suitable for injection, p.o., and other routes of administration are well known in the art and may be found, for example, in Remington's Pharmaceutical Sciences, Mack Publishing Company, Philadelphia, PA, 17th  
35 ed. (1985). Parenteral formulations must be sterile and non-pyrogenic, and generally will include a pharmaceutically effective carrier, such as saline,

buffered (e.g., phosphate buffered) saline, Hank's solution, Ringer's solution, dextrose/saline, glucose solutions, and the like. These formulations may contain pharmaceutically acceptable auxiliary substances as required, such as, tonicity adjusting agents, wetting agents, bactericidal agents, preservatives, stabilizers, and the like.

The formulations of the invention can be distributed as articles of manufacture comprising packaging material and a pharmaceutical agent which comprises the C5 blocker or blockers and a pharmaceutically acceptable carrier as appropriate to the mode of administration. The packaging material will include a label which indicates that the formulation is for use in the treatment of joint inflammation and may specifically refer to arthritis, rheumatoid arthritis, osteoarthritis, lupus arthritis, psoriatic arthritis, juvenile onset rheumatoid arthritis, reactive arthritis, Reiter's syndrome (Reiter's disease), or other diseases involving joint inflammation.

Without intending to limit it in any manner, the present invention will be more fully described by the following examples. The methods and materials which are common to various of the examples are as follows.

#### MATERIALS AND METHODS

##### Cell Lysis Assays

The cell-lysing ability of complement in various body fluid samples was determined using hemolytic assays performed as follows: Chicken erythrocytes were washed well in GVBS (Sigma Chemical Co. St. Louis, MO, catalog No. G-6514) and resuspended to  $2 \times 10^8$ /ml in GVBS. Anti-chicken erythrocyte antibody (IgG fraction of anti-chicken-RBC antiserum, Intercell Technologies, Hopewell, NJ) was added to the cells at a final concentration of 25  $\mu$ g/ml and the cells were incubated for 15 min. at 23°C. The cells were washed 2x with GVBS and  $5 \times 10^6$  cells were resuspended to 30  $\mu$ L in GVBS. A 100  $\mu$ L volume of body fluid test solution was then added to yield a final

reaction mixture volume of 130  $\mu$ L. As used herein, reference to the serum percentage and/or serum input in these assays indicates the percent of a body fluid (including serum, as well as other body fluids such as blood, plasma, or synovial fluid) in the 100  $\mu$ L volume of body fluid test solution.

After incubation for 30 min. at 37°C, percent hemolysis was calculated relative to a fully lysed control sample. Hemolysis was determined by spinning the cells down and measuring released hemoglobin in the supernatant as the optical density at 415nm.

A 50% reduction in hemolysis after treatment with the C5 blocker or blockers used in the practice of the invention means that the percent hemolysis after treatment was one half of the percent hemolysis before treatment.

Various hemolytic assays described below in the examples were performed using this chicken erythrocyte assay with the following body fluid inputs. For assays of mouse complement activity, the 100  $\mu$ L volume of body fluid test solution contained 50  $\mu$ L of diluted (in GVBS) mouse serum and 50  $\mu$ L of human C5 deficient serum (Quidel Corporation, San Diego, CA). For assays of human complement activity, the body fluid test solution contained various concentrations of human plasma or serum, with hybridoma supernatants and/or GVBS being added to yield the final 100  $\mu$ L volume. For the assays used to screen hybridoma supernatants discussed below in example 8 each 100 $\mu$ L volume of serum test solution contained 50 $\mu$ L of hybridoma supernatant and 50 $\mu$ L of a 10% solution of human serum in GVBS, yielding a 5% human serum input.

#### Collagen Induced Joint Inflammation

Examples 1, 2, and 3 use a collagen induced joint inflammation system that has been employed since the 1970s as an animal model of human joint inflammation, particularly RA (see, for example, Trentham et al., 1977;

Holmdahl et al., 1986; Boissier et al., 1987; Yoo et al., 1988). This model system was implemented using 8-12 week old male DBA/1LacJ mice that were purchased from The Jackson Laboratory (Bar Harbor, ME).

5     Immunization

Bovine collagen II (B-CII) obtained from Elastin Products Company, Inc., Owensville, MO, was dissolved in 0.01M acetic acid by stirring overnight at 4°C at a concentration of 4mg/ml. Complete Freund's adjuvant (CFA) was prepared by the addition of desiccated Mycobacterium tuberculosis H37RA (Difco, Detroit, MI) to incomplete Freund's adjuvant (Difco) at a concentration of 2mg/ml. The solution of B-CII was emulsified in an equal volume of CFA and a 100µl aliquot of this emulsion, containing 200µg B-CII and 100µg of Mycobacterium, was injected intradermally at the base of the mouse's tail. After 21 days, all mice were reimmunized using the identical protocol. This secondary CII reimmunization served primarily to boost the serum levels of anti-CII antibodies in the immunized mice. After CII reimmunization, the onset of joint inflammation (JI) and disease progression rise dramatically, characterized by the severe swelling and redness of the joints of one or more paws at around 4-6 weeks after the initial immunization.

25     Clinical evaluation

Mice were examined daily beginning on the day of reimmunization for the appearance of JI. The presence of JI was determined by examining, measuring and scoring each of the forepaws and hindpaws. Collagen induced JI (CIJI) is characterized by swelling and erythema or visible joint distortion of one or more extremities. The severity of JI in each affected paw was scored as: 0 - normal joint; 1 - visible redness and swelling; 2 - severe redness and swelling affecting entire paw or joint; or 3 - deformed paw or joint with ankylosis. The sum of the scores for all four paws in each mouse was



used as an index (the "JI index") to assess overall disease severity and progression.

#### Anti-complement Monoclonal Antibodies

Monoclonal antibodies that bind to and block mouse C5 were prepared by standard methods from hybridoma BB5.1 (Frei, et al., 1987), which was obtained from Dr. Brigitta Stockinger of the National Institute for Medical Research, Mill Hill, London, England. Anti-human C8 hybridoma, 135.8, which generates an Mab that does not block mouse C8, was obtained from Dr. Peter Sims (Blood Research Institute, Milwaukee, WI). Both antibodies are IgG1 isotypes, and ascites of BB5.1 or 135.8 were obtained in athymic nude mice or BALB/c mice, respectively. IgGs were purified from ascites with a protein A affinity column eluted with acetic acid, and subsequently dialyzed against PBS. Purified antibodies were quantified by spectrophotometric determination of absorbance at 280nm and sterilized with a 0.22  $\mu$ m filter.

#### Antibody administration

For prophylactic treatment, mice were randomly divided as C5 blocker treated and control treated groups and subsequently received 750 $\mu$ g per mouse ip doses of either anti-mouse C5 mAb, BB5.1, or anti-human C8 mAb, 135.8, as a control, twice weekly. For therapeutic treatment of established JI, mice received anti-mouse C5 mAb BB5.1 or anti-human C8 mAb 135.8 at 2-5 mg/mouse ip daily for 10 days after the initial onset of JI was observed. The doses of anti-C5 mAb were adjusted in a range spanning 2 mg to 5 mg per injection to ensure that the desired depletion of C5 mediated hemolytic activity was obtained, i.e., a depletion of at least 50%.

Unlike the situation in humans, where administration of a C5 blocker to a body fluid of genetically unrelated individuals results in roughly equivalent levels of complement inhibition, the dose of anti-murine-C5 mAb required to deplete hemolytic activity by a given amount in mice is strain dependent. The dose required to

deplete hemolytic activity in DBA/1LacJ mice is approximately four times higher than the dose required to achieve an equivalent depletion of the hemolytic activity in BALB/c mice.

5 T cell stimulation assays

Lymph node cells taken from animals at the time of sacrifice were analyzed for specific T cell responses to collagen II. T cells ( $5 \times 10^5$ ) were incubated with  $5 \times 10^5$  mitomycin C (50 $\mu$ g/ml) treated syngeneic spleen cells from normal DBA/1LacJ mice in flat bottomed 96-well plates. Bovine collagen II (B-CII), bovine CI (B-CI), chicken CII (C-CII) and ovalbumin or BSA were added to cultures at 20 $\mu$ g/ml. The culture medium was RPMI-1640 supplemented with 5% heated inactivated FCS,  $5 \times 10^{-5}$  M 2-ME, 10mM HEPES buffer, 1% L-glutamine, 1% sodium pyruvate, and 1% penstrep. The cultures were incubated at 37°C in 5% CO<sub>2</sub> for 4 days. Eighteen hours before harvesting, 1 $\mu$ ci of <sup>3</sup>H-thymidine was added to each well. Results are expressed as cpm obtained from triplicate T cell cultures.

20 Quantification of anti B-CII antibodies

Mice were bled at various times after immunization with B-CII. Serum anti B-CII antibody titers were measured using a conventional ELISA for B-CII similar to the ELISA for anti C5 antibodies described below in Example 8, but using B-CII to coat the plates (also see Myers, et al., 1989, and Seki et al., 1992, for descriptions of similar assays).

25 Histological examination

Mice from each group were sacrificed and all four legs from each mouse were fixed in 10% buffered formalin and decalcified in a solution of 3.1% HCL, 5% formic acid and 7% aluminum chloride. The tissue samples were embedded in paraffin, sectioned at 5 $\mu$ m and stained with hematoxylin and eosin. For immunofluorescence staining, paws were decalcified in a 0.1M Tris solution containing 10% EDTA and 7.5% PVP for 3 days and frozen in OCT at

-80°C. 5 $\mu$ m sections were then prepared and stained with 9FITC conjugated goat anti-mouse IgG, IgA, and IgM (Zymed Laboratories, South San Francisco, CA, Catalog No. 65-6411) at a dilution of 1 to 50.

5

EXAMPLE 1Therapeutic Effects of C5 Blocker Treatment after the Clinical Onset of Collagen Induced Joint Inflammation

In order to assess the effects of administration of a C5 blocker on established JI, mice were observed following induction of CIJI, as described above, and pairs of mice were selected that showed the initial appearance of readily detectable JI symptoms (swollen joints of the paws) on the same day. One mouse of each such pair was treated with a anti-C5 mAb BB5.1 and one was treated with a control injection of either the irrelevant mAb 135.8 or PBS. In each matched pair, the animal with the greatest overall level of paw inflammation was assigned to the C5 blocker treatment group so as to avoid potentially biasing the results in favor of the C5 blocker treatment. Starting on the first day when joint inflammation was observed as paw inflammation, treatments were continued daily for 10 days. (In one case a pair of mice was only carried for 8 days.) In addition to these matched pairs, two unpaired animals also received the C5 blocker treatment after the induction of JI.

Histological examination of initially affected joints from control-treated mice at the end of the treatment period revealed extensive bone erosion with severe inflammatory cell infiltration, thickening of the synovial membranes, and pannus formation (Figure 1b). In contrast, the initially affected joints of the C5 blocker treated group showed preserved joint structure with some degree of thickening of synovial membranes and mononuclear cell infiltration into some of the joints (Figure 1c). The severe inflammatory cell infiltration in the control-treated joints was predominantly made up